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Article information:

To cite this document:
Ozcan Saritas, Liliana N. Proskuryakova, (2017) "Water resources – an analysis of trends, weak signals and wild cards with implications for Russia", foresight, Vol. 19 Issue: 2, pp.152-173, doi: 10.1108/FS-07-2016-0033
Permanent link to this document:
http://dx.doi.org/10.1108/FS-07-2016-0033

Water resources – an analysis of trends, weak signals and wild cards with implications for Russia

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Abstract

Purpose – *This paper focuses on the long-term situation with water resources, and water sector in particular, analyzed through a Foresight study. The authors attribute particular attention to implication for Russia, which is relatively better positioned regarding the availability of water resources. However, the country still faces challenges related to the protection of water resources, drinking water supply, water networks, consumption patterns, water discharge, treatment and re-use. The present study aims at identification and analysis of trends, factors and uncertainties in water supply, demand, use and re-use with a particular focus on sustainability of water systems; water use by households and industry; and new water services and products.*

Design/methodology/approach – *Research methodology in this paper involves a horizon scanning exercise for the identification of the key trends, factors and uncertainties along with the identification of weak signals of future emerging trends and wild cards in the form of future surprises, shocks and other unexpected events that may disrupt the preservation of water resources and the future of the water sector. Trends characterize broad parameters for shifts in attitudes, climate, policies and business focus over periods of several years that usually have global reach. These are usually experienced by everyone and often in similar contexts. Trends may represent threats, opportunities or a mixture of them, identified through underlying processes, possible events and other future developments.*

Findings – *A key systemic restriction of water use for the next decades both globally and in Russia relates to competition between agriculture, energy, manufacturing and household water use. Given that the amount of renewable water resources is almost fixed and even decreases because of pollution, circular economy solutions for water use will be required. Implications of the global trends identified in the study for Russia are dependent on the overall situation with water resources in the country. Russia has sufficient water supply: the overall intake of water for drinking and economic purposes in Russia amounts to 3 per cent of the total water resources, two-thirds of which are discarded back to water bodies. At the same time, there are substantial problems associated with the extremely uneven distribution of water resources across the country, as well as high "water intensity" of the Russian GDP. The Russian water sector is currently not very attractive for investors. Moreover, it has significantly less lobbying opportunities than other infrastructure sectors, and this complicates its institutional and financial positions. Meanwhile, there have been some positive changes with regard to activities with a short pay-off period.*

Originality/value – *The paper offers one of the first studies on the future of Russian water resources with a focus on the water supply and sanitation sector. A comprehensive approach to trends identification (not found in other studies on Russian water resources) allowed authors to identify social, technological, environmental, economic, policy and value-related global trends and uncertainties. Moreover, implications of these trends and uncertainties, as well as Russia-specific trends, were outlined.*

Received 15 July 2016
Revised 25 November 2016
Accepted 10 January 2017

The research leading to these results has received funding from the Ministry of Education and Science of the Russian Federation in 2016-2017 (project ID: RFMEFI60216X0016).

Keywords *Russia, Water resources, Horizon scanning, Sustainable water systems, Water goods and services, Water use*

Paper type *Research paper*

1. Introduction

Access to clean water is a grand challenge (UNESCO, 2015). The intensity of this challenge varies between countries depending on their geographical location and level of socio-economic development. However, what is common is the search for ways to improve the efficiency of water production and use, as well as options to mitigate the impacts of factors affecting water availability, including climatic conditions, natural disasters, demographic changes and urbanization, technological advancements, economic growth and prosperity and social and cultural values (UNESCO, 2012).

Researchers attempt to forecast how these factors will evolve over the next decades and what measures should be taken by consumers and policy makers to address the water-related hurdles and develop a vision for a sustainable use of water resources. In such an attempt in 2011, the experts of the International Water and Sanitation Center note that "water sector operates in a dynamic environment of rapidly changing levels of economic development, demographic change and governance contexts that have significant impacts" (IRC International Water and Sanitation Center, 2011, p. 3). They also note that trends in the sector are very uncertain.

Concerning the availability of water resources, Russia is one of the countries that are relatively better positioned compared to a number of other economies (OECD, 2013). However, there are still outstanding issues linked to protection and use of water resources, water purification and networks, consumption patterns, discharge, treatment and re-use. The present research recognizes that strategies for water resources should be covering the topic in a holistic manner. Therefore, three inter-related domains have been identified to address different aspects of exploiting water resources:

1. sustainability of water supply systems;
2. water use by households and industry; and
3. new water services and products.

The overall research process involves a Foresight methodology (Miles *et al.*, 2016) that begins with an exploratory horizon scanning exercise. The current paper presents the outcomes of the scanning phase, which encompasses the analysis of trends, weak signals of future changes, uncertainties and wild cards in the form of largely unexpected but potentially vital changes related to water resources. The scanning process began with a systematic analysis of social, technological, economic, environmental, political and value/culture (STEEPV) trends to capture the dynamics of change changes related to water resources due to a wide variety of factors. STEEPV is a methodology widely used in foresight horizon scanning exercises for categorization of trends (Andersen and Rasmussen, 2014; Andersen and Andersen, 2016). A horizon scanning of global trends was based on the review of research papers and reports by acclaimed international and national bodies such as UNESCO, Organization for Economic Cooperation and Development and the European Union. The results were discussed and elaborated with experts from Russia, Brazil, India, the USA, Japan and other countries through a scanning workshop held in Moscow in November 2014.

The paper begins with the review of the key issues and challenges related to water resources. Particular attention is paid to the state-of-the-art in the aforementioned three domains that fall in the scope of research. Section 3 details the scanning methodology used for research. Trends, weak signals and wild cards that were identified in the study are presented in Section 4. In the following section, the implications of those trends, weak signals and wild cards on water resources in Russia are discussed. The final section of the paper draws overall conclusions and outlines next steps and follow-up activities toward policies and actions for a more efficient and sustainable use of water resources.

2. Background

Water is vital for human beings, living species, environment and the economy. However, today, water is not equally accessible and readily available around the globe, particularly for poor people living in arid areas and less successful industries that lost cross-industrial competition for water. The reason for this unequal distribution is the cost of water treatment and supply that has to be reimbursed to water supply and sanitation companies either by direct users or by a third party (i.e. government). On the other hand, people have the right to access and use water "for free". This creates a complexity and, frequently, a conflict between water supply and demand.

On July 28, 2010, through Resolution 64/292, the United Nations General Assembly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realization of all human rights (United Nations, 2010). When it comes to enforcement of this human right, UNESCO (2012) distinguishes between the following categories of water consumers:

- ecosystems, for which water demand is determined by the water requirements to sustain or restore the benefits for people;
- energy, for which large quantities of water are used, but rarely reported and thus are poorly known;
- food and agriculture;
- human settlements that require water for drinking and household use; and
- industry.

These five categories will constitute a necessary scope for the analysis of trends and wild cards, which are likely to shape the sustainability of water systems (UNESCO Category 1 of water consumers), water use by households and industry (UNESCO Categories 2-5 of water consumers) and new water products and services (this is related to the water industry itself). Therefore, it is important to set the scene in each category to understand the current context and what is likely to emerge in the future within that context.

The amount of water use has been growing at an alarmingly high speed over the course of the past century. It is projected that *global water demand will increase by 55 per cent in 2050* in comparison with the level noted in year 2000. By the year 2050, 3.9 billion people (or approximately 40 per cent of world's population) will face serious limitations to their water consumption. About 240 million people will not have sufficient access to drinking water, and 124 billion people will not have appropriate facilities for water disposal (i.e. will have inadequate sanitary conditions) (OECD, 2012a).

Water and energy domains are inextricably interlinked. While water is crucial for the production, distribution and use of energy, energy is crucial for the extraction, purification and delivery of water. Long-term water and energy strategies should go hand in hand to assure human health, economic growth and environmental sustainability (Vieira and Ghisi, 2016; Gu *et al.*, 2016). At present, increased global *water consumption is also linked to the increased global energy consumption trend*. In 2010, 15 per cent of the total water consumption was spent on electricity production, which makes up 75 per cent of water resources consumption by industry (OECD, 2012b). As global industrial production is expected to further grow, it will continuously require more power and thus more water. Therefore, programs aimed at the reduction of water resources consumption (deficit) should also include energy efficiency measures.

Water – food – agriculture nexus is also crucial as water is one of the key inputs in the entire agrifood supply chain. Agriculture is currently the largest user of water at the global level, accounting for 70 per cent of total withdrawal (FAO, 2011). On the one hand, water scarcity and decreasing availability of water for agriculture constrain irrigated production overall, and particularly in the most hydrologically stressed areas and countries (UNESCO, 2014). On the other hand, excessive use of water for irrigation leads to degradation of farmlands and causes rise in groundwater level and secondary soil salinization. As a result, the soil becomes inappropriate for agricultural use. Globally, by 2050, there will be much less water left for irrigation, as it will increasingly compete with other human needs.

Demand for water resources in both urban and rural settlements has been increasing dramatically. A substantial part of the world population does not have access to clean water and/or water disposal systems (a pre-requisite for proper sanitation). The UN estimates that 11 per cent of humanity (0.8 billion) cannot access safe water, 17 per cent (1.2 billion) live in regions where water is physically scarce, 22 per cent (1.6 billion) face economic water shortage (inadequate infrastructure/cost) and 36 per cent (2.5 billion) still lack basic sanitation (United Nations, 2013b). UN acknowledged that the Millennium Development Goal (MDG) for sanitation had not been attained by 2015. Therefore, this goal has been retained in the Sustainable Development Goals recently adopted by the UN member states (United Nations, 2015). If no measures are taken, by 2050, 1.4 billion people, mostly in developing countries, are projected not to have access to basic sanitation (OECD, 2012a). Considering the rapid urbanization process, particularly in Africa, South Asia and China, it may be expected that cities will be the main sources of crises related to water, as well as to food and energy.

Water consumed by industry (manufacturing) is used in production processes, for example, for heating, cooling, cleaning/washing, manufacturing and extracting. Industrial water is either provided by a public/private supplier or self-supplied through making use of available ground- and/or surface water resources. Importantly industry is one of the major water polluters. Unfortunately, not all industrial water is treated before disposed into environment. In developing countries, this indicator reaches 70 per cent. Global water withdrawals for industry currently represent 22 per cent of total water use, with 59 per cent in high-income countries and only 8 per cent in low-income countries. In 2025, the industrial withdrawal is expected to rise to 24 per cent of the total water consumption (UNESCO, 2014a).

The present research recognizes that strategies for water resources should be addressed through the lens of integrated water resource management covering the entire water lifecycle. Therefore, three inter-related domains have been identified to address different aspects of water resource management: sustainability of water supply systems; water use by households and industry; and new water services and products. These three domains cover quality of water resources, as well as their demand and supply. Thus, the present study considers the scope of the three sub-categories as follows:

1. The “sustainability of water systems” domain in this study encompasses ground and surface water sources and their condition, factors affecting their quality (including climate change), management of water resources in hydraulic engineering systems, transboundary governance of water bodies recycling and reuse of water and its “micro” and “macro” purification and cross-sectoral water issues.
2. In “new water products and services”, the authors consider challenges in the water industry and economy that create demand for new products and services. The following topics are considered in this sub-category: institutional, regional and national water use issues (groundwater use; water storage; water-energy-food nexus; and culture of water use) and client-oriented products and services.
3. Finally, “water use by households and industry” covers the economy of water resources, changing water use patterns and issues related to water and wastewater companies operation (public and private ownership, water reforms and tariffs, etc.).

Following the scoping of the domains, the next section of the paper describes the research methodology.

3. Methodology and process

The present study aims at:

1. Identifying and analyzing trends, factors and uncertainties in water supply, demand, use and re-use with a particular focus on:
   - sustainability of water systems;
   - water use by households and industry; and
   - new water services and products.
2. Exploring emerging opportunities and threats for the future and assessing their implications for Russia.

Thus, research methodology involves a horizon scanning exercise for the identification of the key trends, factors and uncertainties, along with the identification of weak signals of future emerging trends and wild cards in the forms of future surprises, shocks and other unexpected events that may disrupt the future of the water sector. Scanning is defined by the UK's Chief Scientists Advisers' Committee (2004) as:

> [. . .] the systematic examination of potential threats, opportunities and likely future developments including, but not restricted to those at the margins of current thinking and planning. Horizon scanning may explore novel and unexpected ideas as well as persistent trends and issues (DEFRA, 2002).

Trends characterize broad parameters for shifts in attitudes, climate, policies and business focus over periods of several years that usually have global reach. These are usually experienced by everyone and often in similar contexts. They may be larger than the power of individual organizations and sometimes nations (Saritas and Smith, 2011). Trends may entail threats, opportunities or a mixture of them identified through underlying processes, possible events and other future developments. Most organizations and even nations need to collaborate to change, exploit or mitigate the implications of expected or unexpected events and developments.

By identifying key developments and uncertainties, this horizon scanning study identifies trends in the water sector both globally and in Russia for a discussion on their implications. A STEEPV framework is used to map trends and ensure that a broad range of those is covered (Loveridge, 2002). The set of STEEPV categories is intended to be sufficiently wide-ranging and comprehensive to consider a wide variety of inter-related and inter-dependent issues (Figure 1). It is not a rigorous conceptual framework, but rather a set of categories that have proven to be useful for classifying trends and related factors.

The horizon scanning study was undertaken with a mixture of methods involving scoping, desk research, expert meetings and brainstorming activities. First, a scoping exercise was performed to clarify the focus of the research. Three aforementioned thematic areas, namely, sustainability of water systems; water use by households and industry; and new water services and products, were identified during the scoping meeting. A scoping document was prepared, which describes each thematic area in detail.

Second, a review was undertaken to identify trends in research papers and international and national strategy documents (referenced in this paper). The identified trends were detailed by experts in the three focus areas and were presented at the international expert seminar. The reviewing process also involved the identification of international and national experts from the sector, research institutions, government agencies and international organizations with particular interest and experience in the focus areas. Following the nomination of experts, a second workshop was held on the global trends in the water sector. The workshop involved the presentation of the study goals and methodology. The team members presented the three themes and trends that were identified under each of

Figure 1 STEEPV framework with examples of what is covered under each category

Social	Ways of life (e.g. use of leisure time, family living patterns), demographic structures, social inclusion and cohesion issues (fragmentation of lifestyles, levels of (in)equality, educational trends).
Technological	Rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology (including security and health problems).
Economic	Levels and distribution of economic growth, industrial structures, competition and competitiveness, markets and financial issues.
Environmental	Pressures connected with sustainability and climate change, more localised environmental issues (including pollution, resource depletion, and associated biodiversity, and welfare concerns).
Political	Dominant political viewpoints or parties, political (in)stability, regulatory roles and actions of governments, political action and lobbying by non-state actors (e.g. pressure groups, paramilitaries).
Values	Attitudes to working life (e.g. entrepreneurialism, career aspirations, deference to authority, demands for mobility (across jobs or places, etc.), preferences for leisure, culture, social relations, etc.

them. The international experts from the USA, Japan, India, Moldova and Belarus gave presentations on the international perspectives on the three themes. A brainstorming session was undertaken to discuss the selected trends. The experts had an opportunity to review the lists of trends and to complement them with their knowledge and experience. Experts were asked two key questions:

Q1. What are the trends, issues and uncertainties in the water sector in each theme?

Q2. What would be their implications for Russia?

A STEEPV table was generated to map trends under relevant categories and to indicate the systemic relationships between them.

The paper presents the selection of key trends identified by the research team and complemented, validated and prioritized by the experts through workshop and post-workshop consultations. In the following sections of the paper, trends will be presented, followed by the discussion of their deflection for Russia.

4. Global and national trends on water resources

A list of trends was generated through reviews and workshops, which are presented in the following tables in STEEPV categories:

Global Social trends:

- Persisting water challenges for the poorest people: problems with sanitation and waterborne diseases.
- Extending health impacts of water treatment technologies.
- Increasing risk of water-related conflicts between countries.
- Increasing demand for freshwater because of global population growth.
- A conflict of public and private ownership of water and water systems with human right to water.
- Changing behavioral patterns toward a more rational water use.
- No access to stable water supply for a significant part of the world population creates environmental refugees (i.e. North Africa) and water terrorism.

Social Trends that are more typical for Russia

- The quality of drinking water in water supply systems often does not meet sanitary standards and raises consumer concerns; a significant part of the population uses household filters or purchases bottled water.
- Absence of centralized water supply and disposal in significant number of settlements; in some cities, water supply is available only several hours per day.
- Nearly two-fold decrease in water demand by Russian households over the past 10 years (from 300-380 to 180-200 liters per person per day, for comparison: European level is 120-150 liters). This is largely a result of introducing metering systems and widespread installation of modern plumbing.

Global Technological trends:

- Increasing efficiency of water use through water saving technologies; advancing technologies for treatment and recycling of water and promotion of zero-discharge in water bodies.
- Increasing availability of water cleaning and filtering technologies.
- Introduction of centralized information systems for measuring resource use (beyond meters).
- The widespread use of smart metering and payment technologies to enable variable tariffs for different users.
- Differentiation of water supply technologies depending on the size of settlements; persisting challenge of water supply in rural areas and poor cities because of high cost of connection to centralized water pipes and treatment systems and inability to provide a similar level of water quality through small-scale water supply systems.
- Increasing efficiency of irrigation technologies (i.e. transition to drop irrigation).
- Advancing technologies that enable 100 per cent water desalination for drinking purposes; quick cost-cutting enhances rising demand.
- Spreading solar desalination technologies allowed for reducing the costs of desalinated water two-fold; strong estimates of additional possibilities to cut the price further down as much as three to four times.
- Gradual replacement of chemicals by membranes for water treatment; the spread of reverse osmosis technology for water desalination.
- Gradual replacement of chlorine water purification by ultraviolet disinfection.
- The challenge of water evaporation from water bodies (the volume of water that evaporates from water bodies exceeds world domestic and industrial water withdrawal) makes countries build mid-scale reservoirs and develop chemical covers and leak proof puddles.
- Water resources consumption is increasing because of increased energy consumption. Thus, the most promising and cost-efficient technologies are combo water-energy solutions based on water re-use in the energy sector.
- Spreading nuclear desalination through the use of small- and mid-sized reactors becomes one of the most attractive tandems in water-energy nexus.

Technological Trends that are more typical for Russia

- Insufficient wastewater treatment in the majority of industrial enterprises and utilities leads to the deterioration of water facilities; and the deterioration of water supply-disposal infrastructure (exceeds 60 per cent, annual replacement of pipelines less than 1 per cent instead of required 5 per cent), which causes relatively low technological efficiency and higher number of accidents.

Global Economic trends:

- Greater competition of goods and services in the water market.
- Growing need to design new, more customized business models in water management (e.g. limited water availability may force companies to move to other regions).
- Wider application of future-oriented risk analysis in water-dependent sectors.
- Priority development of water-intensive sectors.
- Wider application of mapping techniques and measuring the level of government investment.
- Increasing availability of financing for industrial and urban water treatment.
- Increasing water export and trade of "virtual water" between water-supply and water-deficit countries.
- Broad discussions of water-consuming hydraulic fracturing technologies (including shale hydrocarbon extraction) in water-stressed countries.
- Increasing attention to water management from world business leaders; eco-friendly water treatment and use may assure extra market value for firms.
- Increasing investment attractiveness of the water infrastructure in developing countries, which ranks third after transport and energy.

Economic Trends that are more typical for Russia

- Positive results of measures with a short pay-off period, for example, energy service contracts, including the installation of private meters and optimization of the hydrodynamic modes of payment that allow saving on electricity costs.
- Adoption of long-term tariffs for water supply-disposal services starting 2016 and, at the same time, persisting artificial tariff control that decreases investment attractiveness of the sector.
- Institutional problems in the water supply to apartment buildings after the switch to metering systems; water supply companies loose access to apartment meters.
- Steadily growing debts of Russia's water utility enterprises are due to decreasing tariff revenues and inadequate accounting for technological losses.

Global Environmental trends:

- Increasing pollution of water basins – rivers, ground water, etc., especially in developing and under-developed countries.
- Climate change, including desertification and ice caps melting; higher frequency of extreme weather phenomena (floods and droughts).
- Widespread adoption of the "zero-discharge" concept, i.e. no water is discharged to rivers, but repeatedly treated and re-used.
- Critical decrease in groundwater levels around industrial areas.
- Gradually increasing population that live in areas at risk of flooding.
- Growing share of water-related disasters in Asia (nearing 90 per cent).
- Escalation of problems related to transboundary water pollution.
- The deterioration of hydraulic structures and reservoirs increases the risk of disasters, especially in flooding periods.

- Environment-unfriendly virtual water flows (national and international) from often dry rural areas to higher population urban centers.
- Construction of new canals, dams and reservoirs provide water for economic use, but at the same time can destroy local fisheries, farming and traditional recreation zones.

Environment Trends that are more typical for Russia

- Insufficient water treatment leads to serious environmental consequences.
- Widening exports of Russian water products and services to Chinese and other BRICS markets.
- Increasing threat of water deficit for certain water basins in Russia's East (i.e. Selenga river in Buryaria Republic because of development of ore mining in Mongolia).
- Seasonal changes in water supply and their consequences (e.g. water transport accidents in Central Russia, etc.).
- The excess rate of groundwater use compared with the rate of its replenishment; the exhaustion of groundwater gradually becomes a threat to sustainable water supply in some regions.
- The increasing pollution of water sources with runoff flows, containing "micro-pollutants" (i.e. chemicals including medical waste, household chemicals, dyes, etc.).

Global Political trends

- Water regulation by governments (in particular, through strategy-making and promoting innovations); loss of certain countries' leadership positions at water markets (e.g. Brazil, which is now forced to import the water treatment equipment from China and Finland).
- Increasing competition for water in transboundary river basins is characterized by the escalation of political tensions and even water-related conflicts.
- Privatization of water supply companies.
- Collaboration of multiple water stakeholders.
- Differentiating water supply and sanitation policies for big and small towns.
- Introduction of new normative and tariff policies with diversified regulation.

Changing legal basis for water management

Political Trends that are more typical for Russia

- Critically low cost of water supply and disposal services.
- Normative tariff regulation of water supply-disposal companies.
- Developing the potential of public-private partnership (PPP) to foster competition in water supply and sanitation market (currently, the market share of private water supply operators exceeds 20 per cent; however, this has not led to significant changes).

Global Value/cultural trends

- Changing lifestyles and water consumption patterns; increasing quality of life associated with higher water consumption.
- Changing attitudes toward state policy and complying with it.
- Water perception as a free gift of nature, typical in water-rich world regions (especially spread in rural communities that do not have water meters, which leads to a permanent wasteful water use and may eventually lead to local crisis situations.

Value/cultural Trends that are more typical for Russia

- Irrational water resources use in industry and agriculture that gradually creates water resources deficit escalating in several regions of the country.

The above list of trends was then prioritized for their relevance to Russia by the experts that participated in the second workshop. A total of 25 trends were selected out of 60 presented above. The shortened list included nine trends related to sustainability of water supply systems; seven trends for water use by households and industry; and nine trends for new water services and products. These are elaborated further in the next sections of the paper. Following the descriptions through a second round of prioritization, three trends were selected under each topic as the most important and critical ones. These will be presented in a table at the end of each section below.

4.1 Sustainability of water systems

It is projected that *global water demand will increase dramatically in the future* (by 55 per cent in 2050 in comparison with the level noted in year 2000). This will rank water sector third by the volume of attracted infrastructure investment after transport and energy. World Health Organization's (WHO's) study for quantifying the impact of projects, aimed at advancing water quality, identified the main *economic benefits of investments in drinking water purification*. The overall gain projected by the WHO equals US$84bn per annum. The breakdown of the key impacts from achieving the MDGs for water and sanitation are presented below in Table I (Hutton and Haller, 2004).

One of the main difficulties on the way to a more efficient water use is the insufficient volume of investments in the water sector. The obstacle in attracting investments is that despite the expected returns, investor and beneficiary are usually different persons. As one may conclude from the aforementioned list, the added value of the water investments is gained not only by end-users but also the society as a whole: the government saves money on emergency costs, tourism is advancing and the health-care system becomes more efficient. It is nearly impossible to channel these benefits in the form of dividends to a particular investor.

The necessary investments in *global water infrastructure* surpass similar cumulative investments in traditional physical infrastructure (roads, railways, telecommunication and energy distribution). This is because of the prolonged exploitation and lack of ongoing recovery of water basins (especially in cases of ponds and agricultural sector reservoirs), the deterioration of hydraulic engineering facilities and siltation of water reservoirs (Tortajada, 2016).

Table I Overall benefits of achieving the MDGs for water and sanitation

Types of benefits	*Breakdown*	*Monetized benefits (in US$)*
Time saved by improving water and sanitation services	+20 billion working days a year	63bn a year
Productivity savings	+320 million productive days gained in the 15-59 age group 272 million school attendance days a year 1.5 billion healthy days for children under five	9.9bn a year
Health-care savings		7bn a year for health agencies 340m for individuals
Value of deaths averted, based on discounted future earnings		3.6m a year
Total benefits		84bn a year

Sources: OECD (2010); Prüss-Üstün *et al.* (2008); Hutton and Haller (2004)

Data for several world regions indicate that in the course of the past 40 years, the rate of *groundwater consumption* has *surpassed the rate of* its *replenishment*. The groundwater depletion is gradually becoming a threat to sustainability of water supply in some regions: it has doubled and reached approximately 280 km^3 in 2000 (for comparison: in 1960, that figure was about 130 km^3). For instance, greater ground water use at the coastal areas leads to ground water salinization that complicates their use for drinking water supply (Wada *et al.*, 2012).

Natural disasters pose a substantial threat to many countries. It is expected that the number of people under the risk of flood will increase from 1.2 billion in 2010 to 1.6 billion in 2050, and the economic value of assets under the risk of flood will rise by 340 per cent (up to US45tn) during the same period. Moreover, the frequency of extreme weather phenomena, such as floods and droughts, is expected to be higher because of climate change (OECD, 2012a), and this requires assuring sustainable water supply in regions mostly affected by these fluctuations, i.e. water storage facilities and water pipelines (Sodhi, 2016).

Accidental water pollution, such as unauthorized discharge, pipeline breakouts and accidents at oil wells, are often complimented by the so-called "micro-pollutants" (i.e. medical waste, used cosmetics and dyes) that gradually accumulate at water sources. *Insufficient pre-treatment of wastewater* before its disposal to canalization by the majority of industrial enterprises and utilities is yet another reason for the deterioration of water treatment facilities of water supply and sanitation companies and eventual pollution (Kong *et al.*, 2015).

Sustainability of water systems is an important factor for preserving water ecosystems and *fishery stock*: among negative impacts are nitrogen and phosphate fertilizers from crop fields and eutrophication processes. Worsening quality of water in bodies due to pollution and climate change processes could also impact fishery stock. Badly designed agricultural and fisheries subsidies could further stress land, water and ecosystems (Nguyen *et al.*, 2016).

Improved water management is essential to regulate competition for water needs among urban and rural regions, industries, energy producers and ecosystems. In the absence of proper water management, water availability may become a major problem already in 20-30 years from now, leading to lost opportunities, health and environmental damage (OECD, 2012a). Among the persistent problems is weak management of water basins, including incomplete set of criteria used for taking decisions on the distribution of water resources among users (Eshtawi *et al.*, 2016).

Water basins and systems are not always located within boundaries of one country. The *transboundary* nature of *water bodies and basins* has important consequences for their *governance* and may lead to political tensions and non-efficient distribution of water resources (United Nations, 2013a). Mesopotamia, Nile and Amu Derya basins can be considered among the most vulnerable areas for conflict (Peek, 2014). Imbalance and eventual problems in the distribution of water resources are observed within the boundaries of individual countries too, such as in the Amazon basin (Shi *et al.*, 2016).

Furthermore, we note the *absence of regulations and mechanisms for the functioning of the water market* in the (inter)national distribution of water-intensive products manufacture and diversion of runoff. Substantial differentiation between groups of countries occurs in the rational water use (quantitative attributes) and the condition of water resources (qualitative attributes) (Soncini-Sessa *et al.*, 2007). OECD member-countries show positive dynamics in indicators reflecting both rational water use and condition of water resources, unlike other groups of countries, including the BRICS (OECD, 2012a).

The key trends in sustainable water systems are related to climate change, non-efficient water resources distribution and water management (Table II).

Table II Trends in sustainable water systems

Contribution	*Trends*
Climate change	Higher frequency of extreme weather phenomena (floods, droughts, tsunami), for example, increased number of people and property stock under the risk of flood Negative impacts on water ecosystems, fishery, agriculture, water transport, etc Problems with natural groundwater replenishment
Non-efficient distribution of water resources	Increased demand for water around the world because of growing population and economy leads to higher competition for limited water resources that results in inefficient allocation of water resources among different industries and sectors of economy, between countries for trans-boundary water basins and between (groups of) people Growing share of world population with lack of access to drinking water and appropriate water disposal Lack of international regulation and mechanisms for “virtual water” trade
Water management	The rate of groundwater use does not march the rate of its replenishment Ineffective control over water pollution leads to water contamination, including “micro-pollutants” (i.e., medical waste, used cosmetics, dyes) Lack of investment in water infrastructure Deterioration of hydraulic structures and siltation of reservoirs

4.2 Water use by households and industry

A substantial part of the world population does not have access to clean water and/or water disposal systems (a pre-requisite for proper sanitation). In the course of the past 10 years, we have seen an *increase in global water demand and consumption* (OECD, 2012a). During this period, an opposite trend was observed in Russia. The sales volume of utility companies has decreased nearly two-fold. This is partly a consequence of the introduction of own water use systems by large industrial consumers and a result of widespread installation of meters and modern plumbing equipment in the housing sector. Thus, average water consumption by households in Russia has gone down from over 300 liters per person per day (in Moscow from 380 liters) to 180-200 liters. However, there is still a way to go to reach the level of European average of 120-150 liters per person per day (Russian Federal State Statistics Service, 2013).

While in developed countries, there are growing concerns over the *renewal of main water supply and disposal infrastructure*, in some countries of Africa, Asia and the New Independent States (NIS) in Eastern and Central Europe and Central Asia (EECA) (including some parts of Russia), the quality of drinking water in water supply systems often does not meet sanitary standards, and this raises consumer concerns (Bouabid and Louis, 2015; Tortajada, 2016). A significant part of the population uses household filters or buys bottled water. Consequently, in the NIS EECA countries, there is a growing number of cities where waste waters undergo, at best, only mechanical purification, and in many cities, clean water is supplied only for certain hours.

Unlike energy, manufacturing and housing, *irrigation is expected to suffer dramatically* from structural changes in water consumption. Considering that in the next 35 years the overall water demand is projected to increase by 55 per cent and 40 per cent of the world’s population are projected to live in water-stressed areas (OECD, 2012a), by 2050, there will be much less water left for irrigation, as it will compete with other human needs (Fouial *et al.*, 2016).

Today, new water treatment technologies, such as *low pressure membrane technologies,* have seen wide industrial applications (i.e. for secondary water use in Singapore, desalination in Israel, etc.). Compared to other technologies with the same effect (i.e. biomimetic nanosystems), these technologies are used at the biggest scale. They are widely discussed at business and research fora[1] and in specialized research centers[2]. As of 2008, the greatest installed volume was in the Americas (44 per cent in the USA), in Europe (19 per cent including Eastern Europe and a few in neighboring states) and in the Pacific Rim (23 per cent) (Furukawa, 2008). In 2012, the US Department of the Interior published experimental results of a data-driven analysis to evaluate the technical and economic factors that impact lifecycle costs for low-pressure (microfiltration and ultrafiltration) membranes. The researchers quantified differences in the fouling propensity for an alumina ceramic and a polyethersulfone polymeric ultrafiltration membrane (Guerra and Pellegrino, 2012). Generally, these technologies are expensive and only cost-effective if payments for water use are sufficient to cover the costs. For instance, the cost of water supply and disposal services in Russia and NIS EECA countries is critically low, which not only makes membrane technologies economically inefficient but often leads to bankruptcy of the water supply enterprises, especially in towns and small settlements. Also, 1 m^3 of water in the Russian water supply system costs less than RUB 30 (in 2013), cheaper than a 0.5 liter bottled water.

Furthermore, water *tariff regulation* methods applied to water supply and wastewater disposal companies in developing countries and some of the new market economies (including NIS EECA) are often conducted based on political (social) rather than economic considerations. For example, in calculating expenditures, the companies take into consideration normative losses (instead of actual losses) (Barbosa and Brusca, 2015; Grafton *et al.*, 2015). This distorts the real picture: if losses are insignificant, why upgrading the networks?

Trends in individual and industrial water use could be grouped into those related to water infrastructure and tariff policy and those linked with investment policy and institutional ones (Table III).

4.3 New water products and services

On the user side, researchers note slow evolution of *water use culture* that implicitly impacts on a wide range of aspects within water use among households. Even the developed

Table III Trends in household and industrial water use

Contribution	*Trends*
Water infrastructure and tariff policy	Ineffective policy instruments or implementation oversight lead to industrial enterprises discharging wastewater outside proper disposal systems
	Lack of funds for upgrading or replacement of main water supply and disposal equipment and infrastructure
	Scale optimization of water supply enterprises and their activities (to overcome the inefficiency of water services in small towns and settlements)
	The price of water supply and wastewater disposal services in Russia and the former Soviet countries is kept extremely low, and its increase rates are below inflation
	Tariff regulation of water supply and wastewater treatment in Russia and the former Soviet countries has political (rather than economic) reasoning
	Persisting wasteful water consumption patterns among population and households
Investment policy	Advancement of public-private partnerships (PPPs) (in developing countries) and public sector borrowing (in developed countries)
	In Russia, the 10 years of PPP experience did not provide a significant difference in enterprises' performance as compared to other institutional alternatives
	Re-munipalization of water supply and disposal enterprises in Europe
Institutions	"Regionalization" of water business: horizontal *vs* vertical
	Institutional problems related to multi-apartment houses water supply, including metering and connection to water supply systems by developers

countries apply a combination of measures, including tariff regulation and intense PR and awareness-rising campaigns to promote water-friendly equipment (e.g. double-splash toilets) and change water-use practices. Given the global urbanization trend, this cultural aspect plays a continuously growing role (Gao *et al.*, 2014).

On the production side, the use of chlorine and chlorine compounds for drinking water treatment in some countries (including many Russian cities) increases the risk of morbidity. However, for *least developed economies*, the implementation of basic treatment processes (even individual chlorine purification) and development of simplest irrigation systems could have a profound positive effect on economic growth and contribute to a better health care.

The costs of access to clean water rise in many countries around the world following the escalation of water stress. For individual water use, it means lower quality of life and higher degree of uncertainty associated with the establishment of property rights on water. For municipal water use, it means that rural areas and slums are weak competitors for scarce water resources, and it poses a huge social problem. Among industrial and agricultural water users, enhanced cross-industrial competition for water creates a need for higher productivity. Technology solutions aimed at addressing this challenge are directed toward *design of new less water-intensive production processes and equipment* (Dellachiesa and Myint, 2016).

The aforementioned UN resolution on human rights to water and sanitation is a great human rights achievement and, at the same time, a limitation for *market mechanisms of water-pricing and water supply companies privatization* as advised by the World Bank. For many developing countries, the World Bank funds represent a unique opportunity to renovate their obsolete water systems. For instance, in Bolivia, the Philippines and Tanzania, quick liberalization of the water industry led to serious conflicts between poor population and local authorities. Thus, a human right to water may represent a constraint for investors.

Privatization of water services may also distort the distribution of water resources among users. The latter is often a requirement put forward by international financial institutions that provide financial support (mainly credits, but also grants). It may cause substantial social risks (that have to be carefully evaluated) in *developing countries* with large share of poor population. The most famous example is a so-called "Water war" in Cochabmba, Bolivia (Olivera and Lewis, 2003; Nickson and Vargas, 2002; Spronk, 2007).

When tackling water services issues, developing countries face the operating costs *vs* capital expenditures dilemma: in the past years, many of them have gradually raised water tariffs. However, this additional money is spent to cover growing operating costs and not to modernize obsolete water supply systems. This creates a vicious circle. Freezing of tariffs, in contrast, makes water sector unattractive for investors.

The trade of real water between water-rich and water-poor countries is usually impossible because of long distances and associated high costs, while the *trade of* "virtual water" happens often and is usually hard to notice and to account for. The "virtual water" concept was first introduced by Allan (1993, 1994) and refers to the water used for the production of an agricultural or an industrial product. Thus, if a country exports a water-intensive product, one may say that it exports "virtual water". In this way, some countries satisfy the water needs of other countries (Hoekstra and Hung, 2002). Most importantly, "virtual water" may become an alternative water source, but it needs to be wisely used. The current trend is increasing the international trade of "virtual water" (in the form of water intensive products) between water-scarce and water-rich countries. It happens that national, international and global transfers of water occur from (often dry) rural areas to more populated urban centers. The existing studies estimate global virtual water trade between nations in 2000 to be from $1,340 \times 10^9$ to $1,138 \times 10^9$ m^3 per year for exporting countries (683×10^9 m^3 for importing countries) (Hoekstra and Hung, 2002, 2003; Chapagain and

Hoekstra, 2003; Oki *et al.*, 2003). These important developments make researchers talk about the water footprint (Ercin and Hoekstra, 2014; Mekonnen and Hoekstra, 2011). The "virtual water" consumption by industry and agriculture is presented in Table IV.

One of the new trends that we observe today is the dawn of the actual (not virtual) water trade. Pure water seems to become an increasingly tradable good. Some experts expect that in the middle of the twenty-first century, fresh water from lake Baikal might be comparable with petroleum in the Russian exports (Fedorov, 2016). Importantly, threats to sustainability of water ecosystems in case of large water intake from water bodies like Baikal should be taken into account.

The *climate change* makes dry areas become dryer and warmer, and other regions, especially tropical ones, face more frequent and large-scale floods. Another consequence of climate change is the higher probability of natural disasters: since the 1950s, the number of natural disasters has risen exponentially, and water-related disasters (either droughts or floods) represent more than one-third of the total. This challenge *requires considerable adaptation of existing water systems* – building new reservoirs, improving flood management and developing anti-evaporation and leak-proof technologies (OECD, 2012a).

Developing countries face the biggest challenges in water use and management – almost all of them experience water shortage and deteriorating environment partly because of fast urbanization. China and other developing countries have to solve several problems simultaneously: develop large-scale infrastructure projects, establish or modernize municipal water systems and increase water sector productivity. At the same time, these countries ought to rebalance their water use structure and upgrade respective institutional regulations for national and trans-boundary basins (FAO, 2003; Stanford University, 2010).

Developed countries are the major producers of water-related technological innovations and have the most advanced water-use policies. This is true for Europe (i.e. European Water Initiative), Asia (with Singapore and its best practices) and North America (i.e. International Joint Commission that manages US-Canadian Great Lakes). Groundbreaking water treatment and recycling technologies and eco-neutral infrastructure projects represent the main focus of innovative water technologies in these countries.

In both developing and developed countries, the main institutional principle of the water sector is conservatism, given its social implications. There are various *legal forms that water supply and wastewater disposal enterprises* assume. In developed countries, public enterprises dominate the picture:

Table IV Actual and virtual water consumption in selected countries, 2006-2014

Nation	*Per capita withdrawal (liters/p/y)*	*% domestic*	*% industrial ("virtual water")*	*% agriculture ("virtual water")*	*Year*
Brazil	297,000	28	17	*55*	2006
Russian Federation	546,000	19	*63*	18	2000
India	627,000	7	2	*90*	2010
China	425,000	12	23	*63*	2007
USA	*1,518,000*	13	*46*	41	2005
Japan	696,000	20	18	*62*	2000
Germany	463,000	12	*68*	20	2001
Worldwide	681,358+	10	20	*70*	2014*

Notes: *Worldometers, 2014, Annualized from 1 January – 6 November 2014, UN statistics
Source: Gleick *et al.* (2011)

- The "German model" is based on joint-stock companies, usually owned by local authorities.
- In the "French model", there is a high share of public-private partnerships (PPPs).
- In the "England's model", water supply infrastructure is privatized on the basin principle (not on the settlement principle) (Saritas *et al.*, 2015).

Furthermore, in continental Europe, investments in the sector are usually attracted through public borrowings (i.e. municipal bonds), even in the case of PPPs. The reason for this is rather pragmatic: public borrowing is cheaper than private. Of fundamental importance is that investments are rarely made from the operating budget and loans are paid back depending on economic activity of the water supply enterprises (Mandri-Perrott and Striggers, 2013).

In developing countries, funding for the water sector usually comes from PPP contracts and private investments (because of high risk of budgetary borrowings) (World Economic Forum, 2005).

The problem of *scale optimization of water supply enterprises* and their activities is common for many countries. In small settlements (towns), limited activities lead to the lack of managerial and technical competences and to high cost per unit (coupled with lower consumers' purchase power). In the European Union, scale optimization is solved through establishing horizontal links either by creating one inter-municipal company in several settlements through the merger of assets (e.g. Poland and the Czech Republic) or by conducting inter-municipal competition for selection of a private operator for several municipal institutions (e.g. Romania). Some recent developments point to "remunicipalization" of the public services sector in the European Union, including water.

Policy makers should be aware of the water use history and state-of-the-art in this sphere. These insights are a good basis for more accurate assessments of water use by industry and households and water restrictions that feed into the new water management programs.

Emerging trends related to water *products and services* were classified by their type of contribution. These trends are linked to either solutions increasing productivity or the availability of water resources, or aim to physically reallocate existing volumes of water. Trends in water products and services could be grouped into those that are aimed at attaining higher productivity, as compared with existing solutions, provide users with additional resources and offer infrastructure solutions (Table V).

Summing up the above outline of major trends that were grouped around the following larger areas: "water use by households and industry", "sustainability of water systems" and "new water products and services", we may conclude that these water challenges should be properly addressed through integrated water management.

Table V Trends in new water products and services

Contribution	*Trends*
Ensuring higher productivity	Combo water-energy technologies Water-saving technologies (bio-gas recovery systems, water meters, ultrasonic sludge pre-treatment, pipe rehabilitation and relining systems and water derivative products such as water-free toilets) Increased competition from Asia (especially China) in higher-end of water products and services
Provision of extra water resources	Desalination (new methods, solar and nuclear options) Treatment (UV and membranes *versus* chlorine and other chemicals)
Infrastructure solutions	Multifunctional dams Small and mid-sized water reservoirs, chemical covers and leak proof puddles Country-wide channels

By *mapping water use* and comparing it to economic value, policy makers can see where this limited resource is of most benefit. Moreover, it is necessary to monitor the flow of water from environment to the economy and back (Australian Bureau for Statistics, 2012).

The main trends that were identified above are the likely global developments in the sphere of water resources. However, they could be diverted or completely reversed by certain factors, which seem unlikely or are little known at present. These factors are known as weak signals and wild cards (Saritas and Smith, 2011). The weak signals and wild cards, identified in the project, range from big ocean current shifts to pandemics that radically change water demand practices (Table VI).

Table VI Weak signals and wild cards in the project's thematic areas

	Weak signals	*Wild cards*
Sustainability of water systems	Water loss/contamination in aging urban pipes "Freaky weather", like drought in nations' breadbaskets (i.e. California) "Freakish" aquatic life: intersex fish, mutant frogs and toxic shellfish	Catastrophic contamination of drinking water due to industrial activities (e.g. the extraction of shale hydrocarbons or radiation) Nuclear accidents contaminated aquatic food webs (e.g. Chernobyl and Fukushima) Exotic pollutants bypass water treatment (e.g. medicine, nanoparticles and pathogen) Big ocean currents shift, changing climate and weather across continents
Water use by households and industry	Illegal water taps continue in urban slums The World misses the UN Sustainable Development Goal (SDG), associated with water supply and sanitation targets and indicators The spread of pandemic diseases carried in water (e.g. Ebola in West Africa)	Society rejects cost to give or sustain clean water for everyone everywhere "Back to basics": demand drops for bottled water and "virtual water"-intensive products Pandemic changes water demand patterns, limits water operating and maintenance capacity Hydro-hegemons assert power or hydro-terrorists act (e.g. in Iraq) Decentralized/on-site water harvesting, treatment and reuse becomes viable Hydrosphere geo-engineering (e.g. refilling Lake Chad, Dead Sea, Lake Balkash, depleted aquifers, etc.)
New water products and services	Hegemons ignore water-sharing treaties and threaten neighbors with international violence	Energy-for-water trading or water cartels become economically and politically viable "Hot" superpower war disrupts global trade, SDG investment and development aid Hydrogen fuel cells proliferate, with pure water as byproduct

Source: Sklarew (2015)

No matter how improbable weak signals and wild cards seem, all of them are based on certain signals that need to be taken into account. In mathematical models, the probability of the phenomena occurrence may be calculated. For instance, extreme weather phenomena (i.e. droughts and tsunami) are already predicted by private and state agencies based on satellite and other data with the use of special software (Lubchenco and Hayes, 2012).

5. Conclusions: implications for Russia, discussion and next steps

Based on the above analysis, it is concluded that the three thematic areas identified for the study are complementary and overlap in a number of issues, including the impact of climate change and its consequences, the limitations to virtual and actual water consumption that require water-saving and water-reuse solutions and the differences in approaches to water management in different country groupings and in different regions of one country.

Implications of these trends for Russia are dependent on the overall situation with water resources in the country. The overall intake of water for drinking and economic purposes in Russia amounts to 3 per cent of the total water resources, two-thirds of which are discarded back to water bodies. The country is among those with sufficient water supply with little less than 20,000 m^3 of water per person per year[3] (UNESCO, 2012a).

The water management measures in Russia deal with the proper operation of utilities and sustainable development. The comprehensive policies should cover measures that interlink tariffs, infrastructure, investments and institutions.

The new products and services that are in line with the main trends and address existing challenges in Russia are related to advancements of infrastructure, increasing the volume of water resources (through making accessible previously unavailable resources or through re-use of existing stock) and their productivity.

A key systemic restriction of water use for the next decades both globally and in Russia relates to competition between agriculture, energy, manufacturing and household water use. Given that the amount of renewable water resources is almost fixed and even decreases because of pollution, circular economy solutions for water use will be required.

In the Russian rural areas, drop irrigation becomes an imperative. This technology, mainly applied in developed countries and those countries that do not make water artificially cheap for farmers, may substantially decrease water intensity in agriculture. Moreover, drop irrigation prohibits soil and ground water pollution by fertilizers and also entails a substantial cost decrease for farmers. All of these implications are beneficial for the environment and health, especially in dry areas and areas of high water demand, such as in new farmlands in Africa owned by Chinese, Indian and Middle East investors.

The challenge of water supply in rural areas and poor city suburbs is especially evident in large countries such as Russia: a connection to major water pipes and water treatment systems becomes very expensive, and small-scale treatment systems typically cannot provide a similar level of water quality. Thus a substantial part of Russian settlements do not have a water supply and disposal system.

The Russian water sector is currently not very attractive for investors. It has significantly less lobbying opportunities than other infrastructure sectors, and this complicates its institutional and financial positions (Platonova and Chernyshev, 2016). Meanwhile, there have been some positive changes with regard to activities with a short pay-off period. In particular, it concerns the widespread energy service contracts for installation of private meters and optimization of the hydrodynamic payment modes that result in water and electricity savings.

The paper explored and discussed a set of critical trends, issues, uncertainties and wild cards related to water resources. These trends represent both challenges and opportunities that stem from both the external environment developments, such as broader socio-economic changes, and internal dynamics in the water sector, such as the development and application of new technologies, products and services; changes in national and regional water policies; and patterns of water use by consumers.

Effective strategies that aim at systemic transformations in the water sector require due consideration of the interrelationships and interdependencies of a broad range of STEEPV trends and issues, as well as weak signals and wild cards that were identified through the paper. An ideal next step that will bring this scanning study further is to build scenarios for the long-term future to illustrate how these complex relationships might work and what sorts of consequences may arise. Thereafter, national, regional and corporate strategies may be developed based on future visions and targets with the identification of promising science and technology areas, policy measures and action plans.

Notes

1. Such as the conference “Advanced Membrane Technology VI: Water, Energy, and New Frontiers” (ECI Conference Series) to be held in February 2015 in Italy.
2. Such as UNESCO Center for Membrane Science and Technology at the University of New South Wales, Australia.
3. The UN Economic Commission for Europe defines countries with poor water supply as those with less than 17,000 m^3 per person per year.

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